Effects of UV Irradiation on Nymphs of Five Species of Cockroaches[1,2]

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ABSTRACT

Effects of UV irradiation on early instars of *Periplaneta americana* (L.), *Blattella germanica* (L.), *Byrsotria fumigata* (Guérin), *Eublaberus posticus* (Erichson), and *Diploptera punctata* (Eschscholtz) were investigated. A higher mortality occurred among nymphs irradiated with UV light from a germicidal lamp slightly before or immediately after they molted than at any other time during an instar, and early instars were more sensitive (determined by mortality rate).

The lethal action of six different monochromatic UV wavelengths (254, 280, 297, 313, 350, and 365 nm) also was investigated. The 254-, 280-, and 297-nm wavelengths produced mortality, and the 254-nm wavelength was most effective.

When newly emerged or newly molted nymphs are irradiated with UV light from a germicidal lamp, tanning is inhibited; the degree of inhibition varies with dose.

Of numerous studies on effects of UV irradiation on insects, most have dealt with either the attraction or repellence or the mutagenic effects of certain wavelengths. However, the direct lethal action of UV on insects has not been studied so extensively. Only few workers have shown that insects were susceptible to the lethal action of UV irradiation. Berthold (1933) found that, in the honey bee, *Apis mellifera* L., worker and queen larvae were highly susceptible to wavelengths shorter than 297 nm. All preimaginal nymphs of the large milkweed bug, *Oncopeltus fasciatus* (Dallas), which were irradiated by Wells and Hamilton (1953) with short-wave UV, died within a few days. Pupae of the confused flour beetle, *Tribolium confusum* Jacquelin duVal (Henzlik 1964), eggs of the tobacco budworm, *Heliothis virescens* (F.) (Guerra et al. 1968), and nymphs of the American cockroach, *Periplaneta americana* (L.) (Wharton 1971) were susceptible to irradiation with short-wave UV. Beard (1972) showed that different stages of several species of insects were sensitive to UV.

Here we demonstrate the effectiveness of certain UV wavelengths in producing mortality among nymphs of several species of cockroaches and the ability of 254 nm of UV light to inhibit cuticular tanning.

MATERIALS AND METHODS.—Nymphs of the following species were used: *P. americana*; the German cockroach, *Blattella germanica* (L.); *Byrsotria fumigata* (Guérin); *Eublaberus posticus* (Erichson); and the Pacific beetle cockroach, *Diploptera punctata* (Eschscholtz). They were fed on Purina Laboratory Chow and water in 250-ml glass beakers and kept in a room maintained at avg 22°C and 50% RH.

UV light sources were a Hanovia low-pressure mercury germicidal lamp which emitted a highly intense dose of UV at 254 nm; a GE AH6 1000 capillary type mercury arc lamp which emitted intense doses of many wavelengths throughout the UV spectrum including 297, 313, 350 and 365 nm; and a Hanovia mercury-xenon compact arc which emitted a continuum of light including a fairly high intensity at the 280-nm wavelength. Germicidal and xenon sources were used because they produced a more intense light at 254 and 280 nm, respectively, than the GE lamp, making possible a shorter exposure period.

Narrow-band pass filters, used in conjunction with the light sources, enabled us to obtain UV light whose peak wavelengths were: 254 ± 7, 280 ± 8, 297 ± 6, 313 ± 10, 350 ± 10, and 365 ± 8 nm. Energies of the various UV wavelengths were measured with an International Light 600/620 Digital Photodosimeter whose photodetector was calibrated in microwatts/cm^2/microamp ($\mu W \cdot cm^{-2} \cdot \mu A^{-1}$) and which could digitally totalize light energy accumulated over any given time period, enabling us to irradiate cockroaches with the same total light energy regardless of wavelength and filter.

Cockroaches were irradiated in a well-ventilated hood; the glass beaker in which the nymphs were kept was 45 cm directly below the UV source. Food and water were removed from the beakers before and replaced immediately after irradiation. Following irradiation, dead and moribund insects were counted daily.

RESULTS AND DISCUSSION.—Various instars of the 5 species were irradiated for 1-h with the Hanovia germicidal lamp. The graphs (Fig. 1–12) of the pooled data of the different instars of each species show that, usually, as Wharton (1971) found in 2nd, and 7th- to 9th-stage *P. americana*, the younger stadia are more susceptible to germicidal UV light. However, not only was the mortality rate of the 3rd stadium of *Blattella* (Fig. 2) slightly higher than that preceding, but mortality rates of the 2nd stadia of *Diploptera* (Fig. 5) and *Eublaberus* (Fig. 4) also were higher than those of the 1st. In cases where the mortality rate of an older instar was greater than the one immediately preceding it, irradiation of the older instar took place closer to the molt.

Comparisons of mortality rates of irradiated 1st instars of *B. germanica* 0–3, 3–4, and 4–5 days old (Fig. 6) showed that those nymphs irradiated immediately after or slightly before molting were more susceptible to germicidal UV than at other times during an instar. Mortality rates of 1- to 2- and 7- to 8-day-old 2nd stadia of *P. americana* (Fig. 7) showed similar results.

Fig. 10 compares mortality rates of *Eublaberus* 1st instars irradiated when they were less than 1-h old and still white to those of nymphs irradiated when they were more than 1-h old and darkened normally. Newly emerged (white) nymphs were more sensitive to short-wave irradiation than older, tanned individuals.

To determine the relative effectiveness of various wavelengths in causing mortality, narrow-band pass filters were used to obtain equal energies (the energy of each wavelength totaled 327 $\mu W \cdot sec/cm^2$) at 365, 350, 313, 297 nm (GE 1000 W lamp), 280 nm (xenon lamp), and 254 nm (germicidal lamp). Nymphs of both *B. germanica* and *P. americana* were sensitive to 254-,

[1] Received for publication Jan. 8, 1973.
[2] Louis M. Roth endorses and communicates.

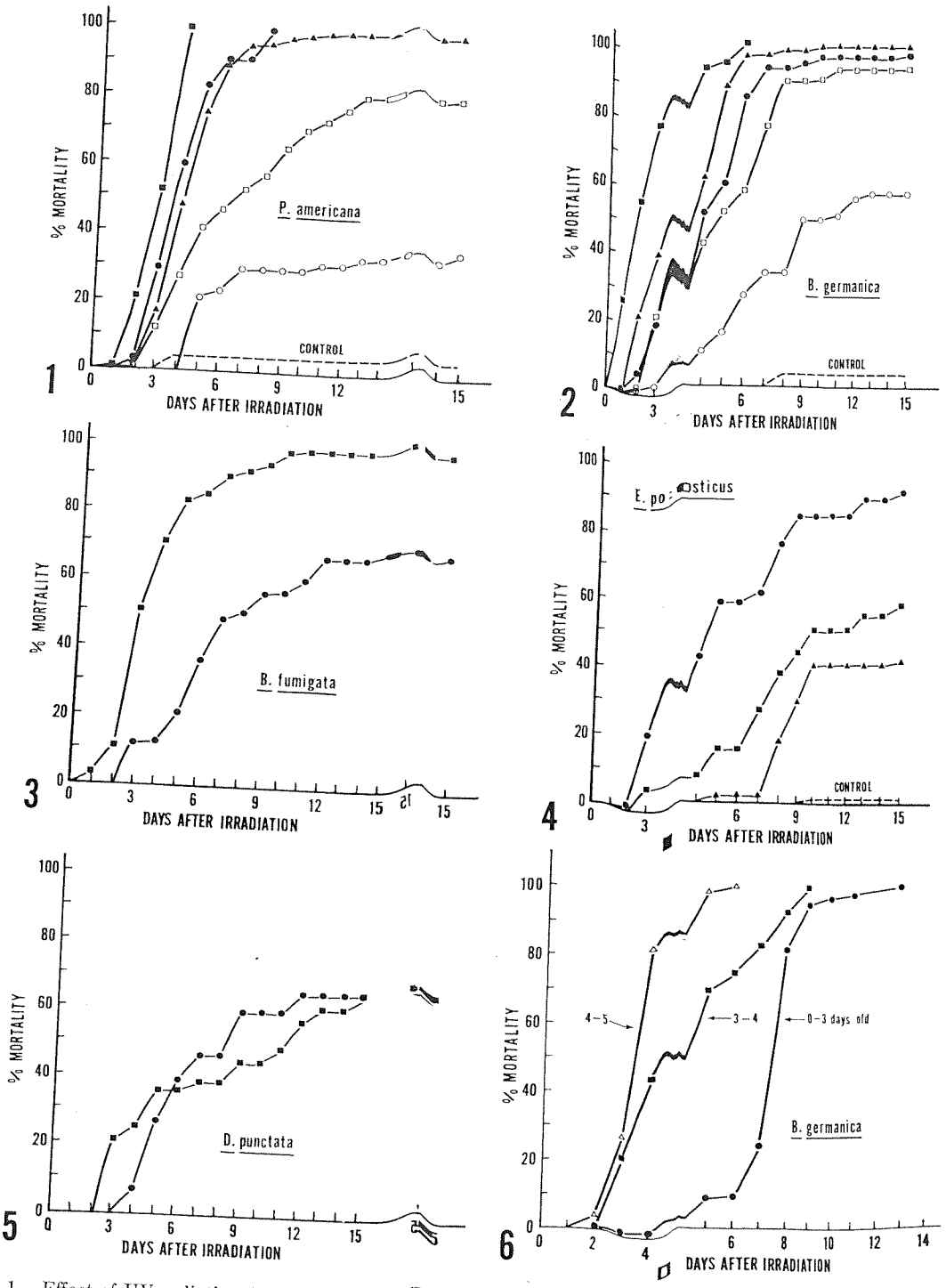


FIG. 1.—Effect of UV radiation (Hanovia germicidal lamp, 3550 μW/cm² for 1-h) on mortality rates of the first 5 instars of *P. americana*. Pooled data on 21, 1st (■), 113, 195, 2nd (●), 415, 3rd (▲) 173, 4th (□), 47, 5th (○) instars. 113 controls.

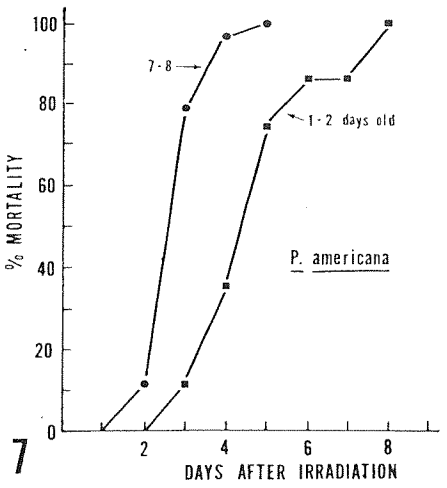
FIG. 2.—Effect of UV radiation (Hanovia germicidal lamp, 3550 μW/cm² for 1-h) on mortality rates of the first 5 instars of *B. germanica*. Pooled data on 160, 1st (■), 231, 2nd (●), 330, 3rd (▲), 153, 4th (□), 140, 5th (○) instars. 83 controls.

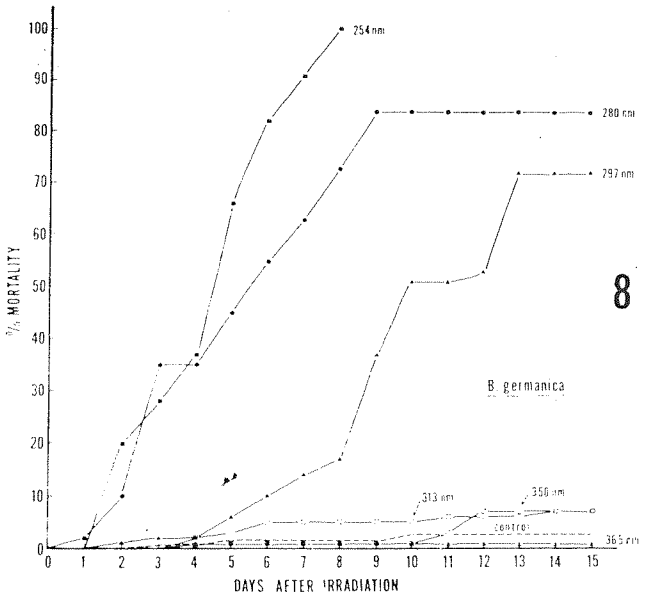
FIG. 3.—Effect of UV radiation (Hanovia germicidal lamp, 3550 μW/cm² for 5-h) on mortality rates of the first 2 instars of *B. fumigata*. Pooled data on 307, 1st (■) and 107, 2nd (●) instars. There were no deaths among the 62 controls.

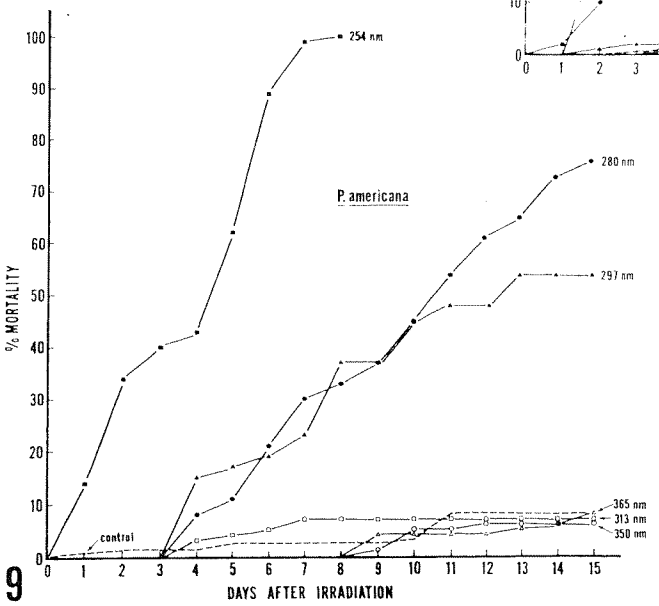
FIG. 4.—Effect of UV radiation (Hanovia germicidal lamp, 3550 μW/cm² for 5-h) on mortality rates of the 1st 3 instars of *E. posticus*. Pooled data on 215, 1st (■), 100, 2nd (●) and 100, 3rd (▲) instars. 135 controls.

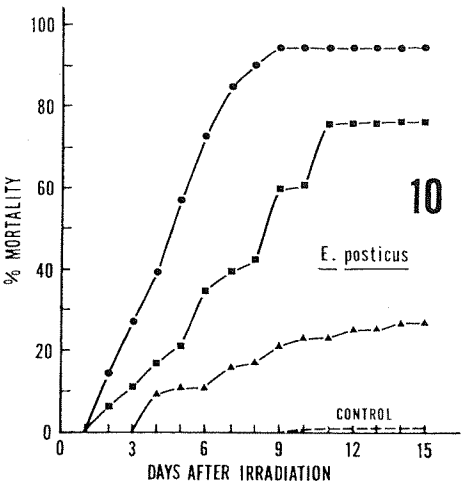
FIG. 5.—Effect of UV radiation (Hanovia germicidal lamp, 3550 μW/cm² for 1-h) on mortality rates of the 1st 2 instars of *D. punctata*. Pooled data on 47, 1st (■) nad 15, 2nd (●) instars. There were no deaths among the 7 controls.

FIG. 6.—Comparison of the mortality rates of the 0 to 3-, 3 to 4-, and 4 to 5-day-old *B. germanica* 1st instars. There were no deaths among the 35 controls.









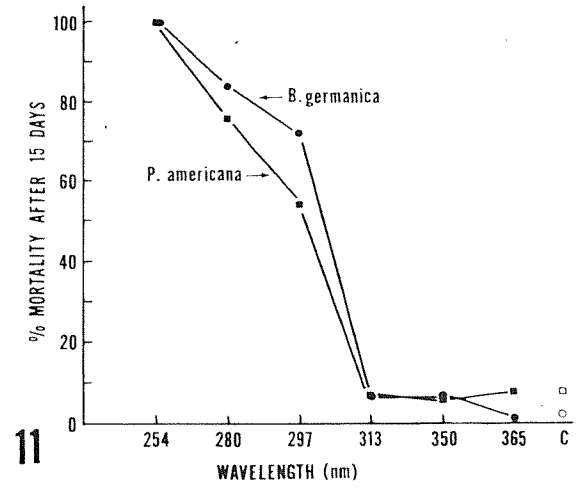


FIG. 7.—Comparison of the mortality rates of 1 to 2- and 7 to 8-day-old *P. americana* 2nd instars. There were no deaths among the 48 controls.

FIG. 8.—Curves of mortality rates of 100 0 to 1-day-old *B. germanica* 1st instars irradiated with 327 $\mu W \cdot sec/cm^2$ energy of 254 nm (Hanovia lamp) (■), 280 nm (Xenon lamp) (●), 297 (▲), 313 (□), 350 (○), and 365 (△) nm (GE 1000 watt lamp). 175 controls.

FIG. 9.—Curves of mortality rates of 100 o to 1-day-old *P. americana* 1st instars irradiated with 327 $\mu W \cdot sec/cm^2$ energy of 254 nm (Hanovia lamp) (■), 280 nm (Xenon lamp) (●), 297 (▲), 313 (□), 350 (○) and 365 (△) nm (GE 1000 W lamp). 160 controls.

FIG. 10.—The effect of UV radiation on the mortality rates of *E. posticus* 1st instars. 84 nymphs less than 1-h old irradiated for 3-h (●). 231 nymphs less than 1-h old irradiated for 1-h (■). 250 nymphs more than 1-h old irradiated for 3-h (▲). (Hanovia germicidal lamp, 3550 $\mu W/cm^2$.) 87 controls.

FIG. 11.—Action spectra plotted against % mortality after 15 days of 100 0 to 1-day-old *P. americana* and *B. germanica* nymphs. C = 100 controls.

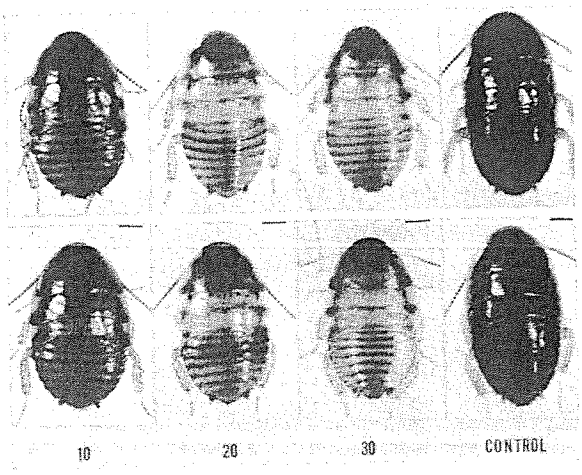


FIG. 12.—Inhibition of melanization of *E. posticus* nymphs irradiated (Hanovia Germicidal Lamp, 3550 μW/cm^2) for 10, 20 or 30 min less than 1 min after they hatched. Upper row, photographed when 24 h old. Bottom row, photographed when 48 h old. Scale = 1 mm.

280-, and 297-nm wavelengths but not to 313-, 350-, and 365-nm (Fig. 8, 9). Greatest mortality occurred after exposure to 254 nm, but high mortalities were obtained also with 280- and 297-nm wavelengths. There appears to be an inverse relationship between wavelength and mortality, the shorter the wavelength the greater the mortality (Fig. 11).

Following the irradiation of *Eublaberus*, not only were mortality rates of newly hatched or newly molted nymphs (white and teneral) higher than older nymphs, but cuticular darkening was either inhibited or delayed. Fig. 12 shows the effect on tanning, where newly hatched (<1-min old) *Eublaberus* nymphs were irradiated for 10, 20, or 30 min with the germicidal lamp and photographed 24 and 48 h later. None of the cockroaches had darkened normally 48 h after irradiation. Tanning was inhibited, and the degree of inhibition varied with the dose. Gingrich[3] showed that UV-exposed tergites of newly molted *P. americana* had damaged epidermal cells, failed to tan completely, and new endocuticle never developed. These factors may have contributed to molting failure at the next instar.

Inhibition of melanization and sclerotization following exposure to short-wave UV occurs also in house fly, *Musca domestica* L., larvae (Beard 1972). As with *E. posticus*, varying degrees of melanization inhibition were observed.

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[3] J. B. Gingrich. 1973. Ultraviolet-induced changes in the integument of newly molted cockroaches (*Periplaneta americana* (L.), Dictyoptera: Blattaria: Blattidae). (In manuscript.)

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